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TITLE OF THE INVENTION

SEMICONDUCTOR DEVICE FOR POWER

CLAIMS

A semiconductor device for power, comprising:

a power element which supplies a load with an operating power;

a temperature detection element which is formed in the same semiconductor chip as that contains the power element, and generates an electric signal corresponding to the temperature of the semiconductor chip;

a reference signal generating means for generating a reference signal corresponding to a reference temperature to be detected;

a comparing means for comparing the reference

signal with a detection signal obtained from the temperature detection element, and detecting the state where the temperature of the semiconductor chip rises higher than the reference temperature;

a control element whose gate is controlled common to the power element; and

a means for correcting at least one of the detection signal and reference signal, based on the current which flows in the control element corresponding to the load current flowing in the power element; wherein

the power element is off-controlled by the detection output from the comparing means.

DETAILED DESCRIPTION OF THE INVENTION

[Field of Industrial Use]

The present invention relates to a semiconductor device for power which has a function of protecting against abnormal temperature by, for example, controlling the current supplied to a load which is used for a large electric power.

[Prior Art]

A semiconductor device for power has a power element to control the current supplied to a load, and a load current flows in this power element. Therefore, the power element is heated corresponding to the quantity of load current. When a fault occurs, for

example, a load shorts, a large current flows in the power element and the temperature of the power element rises extremely.

As the power element temperature extremely rises, not only the power element itself but also other semiconductor elements constructed as one body with the power element or peripheral devices will be broken. Therefore, it is necessary to provide a conventional power element with a protection function to shut off a load current, for example, when the temperature rises extremely.

The above protection function of a power element is conventionally set in a peripheral circuit, but recently, it is studied to provide circuits which detect abnormal states and protect against abnormal states in the same chip as that contains a power element for power for reducing the size and cost and increasing the reliability.

A semiconductor device for power having the above-mentioned protection function is constructed as shown in FIG. 4, and has a power element 11 comprising a p-channel power MOS, for example, so that the current from a power supply 12 is supplied to a load 13 through the power element 11.
The gate of the power element 11 is supplied with a drive signal from a NAND circuit 14. The NAND circuit 14 is supplied with a pulse-like duty-controlled drive

signal from a gate drive circuit 15, and a signal from a comparator 16. Namely, the gate of the power element 11 is supplied with the polarity-inverted pulse drive signal from the drive circuit 15 while the output signal from the comparator 16 is held at a high level, and on/off of the gate is controlled. The comparator 16 is supplied with a reference voltage signal at a point A where the voltage is divided by a resistor circuit, and a voltage signal at a point B which becomes a terminal voltage of a temperature detection diode 17.

The above temperature detection diode 17 is assumed to be provided in the same semiconductor chip as that contains the power element 11. When a large current flows in the power element 11, the power element 11 is heated and the semiconductor chip is heated consequently, the potential at the point B is lowered corresponding to the temperature rise in the semiconductor chip. When the semiconductor chip is held at a normal temperature, the voltage at the point B is set higher than the voltage at the point A, the output signal from the comparator 16 is set to a high level, the power element 11 is controlled by the output signal from the gate drive circuit 15, and the load 13 is controlled as a result. Contrarily, when the semiconductor chip temperature rises, the voltage at the point B decreases. When the semiconductor chip

temperature rises extremely, the voltage at the point B becomes lower than the voltage at the point A and the output signal level from the comparator 16 is lowered. Therefore, in this state, the output signal from the NAND circuit 14 is fixed at a high level, the power element 11 comprising the p-channel MOS is turned off, the load current is shut off, and this semiconductor element is protected from being heated by an overcurrent.

However, in the semiconductor device with the above-mentioned structure, the temperatures of the above heating element and detection element do not necessarily the same, considering the heat conduction between the heating power element 11 and temperature detection element 17. For example, assuming that a short-circuit occurs in the load 13, a large current temporarily flows in the power element 11 and the temperature of the power element 11 rapidly rises, the temperature rise in the temperature detection element 17 which is formed at a different position from the power element 11 can not follow the temperature rise in the power element 11. That is, a temperature difference of about 50℃ exists between the temperatures of the power element 11 and temperature detection element 17. Therefore, even if the protection temperature is set at 150℃, for example, the protection function is executed when the junction temperature of

the power element 11 rises to 200℃ and the element protection function is not perfectly executed.

[Subject to be solved by the Invention]

The present invention has been made in order to solve the above-mentioned problems. Accordingly, it is an object of the present invention to provide a semiconductor device for power having a protection function, which can execute a protective operation corresponding to the temperature of a power element to control a load current in an operation state where a current flows in the power element, and protect the element agains heating even during a temporary temperature rise resulted from a rapid increase of a load current.

[Means for Solving the Subject]

Namely, a semiconductor device for power according to the present invention comprises a control element which is controlled common to a power element to control a load so as to flow a current proportional to the current flowing in the power element, wherein a temperature detection signal from a temperature detection element formed in a semiconductor chip common to the power element is compared with a reference signal corresponding to a preset reference temperature, and the power element is off-controlled in the state where the detected temperature is higher than the reference temperature. And, at least one of the

temperature detection signal and reference signal is corrected by the quantity of current flowing in the control element.

[Function]

In the above-mentioned semiconductor device for power, basically when the temperature of the semiconductor chip in which the power element is set rises over a preset reference temperature, the power element is turned off and the protection against overheating is executed. When such a protective operation is executed, the current proportional to the current flowing in the power element is detected by the control element, and the preset reference temperature is raised by correcting a reference signal by the current obtained from the control element, for example. Therefore, when the power element temperature temporarily rises in the state where the load current flows in the power element unit, the temperature difference between the power element and temperature detection element is compensated, ensuring the protective operation against a rapid increase of load current.

[Embodiments]

Hereinafter, preferred embodiments of the present invention will be explained with reference to the accompanying drawings. FIG. 1 shows a circuit configuration of a semiconductor for power having a

protection function, in which a power element 21 comprises a p-channel MOS. The power element 21 is set between a power supply and a load 22, and is turned on to supply a current to the load 22. A control element 23 comprising a similar p-channel MOS to that of the power element 21 is provided in the same semiconductor chip. The power element 21 and control element 23 are gate controlled by the output signal from a NAND circuit 24, and on-controlled when the output from the NAND circuit 24 is low level.

Supplied to the NAND circuit 24 are the output signal from a comparator 25 and drive signal from a gate drive circuit 26. The gate drive circuit 26 generates a duty-controlled pulse signal, for example. Therefore, when the output signal from the comparator 25 is high level, the polarity of the output pulse signal from the gate drive circuit 26 is inverted and outputted from the NAND circuit 24, and this signal is supplied to the gates of the power element 21 and control element 23.

Supplied through a resistor R3 to the negative side terminal of the comparator is a reference voltage signal at a point A or a connection point between resistors R1 and R2 of a reference voltage setting unit 27 which comprises a voltage divider comprising resistors R1 and R2. The current obtained when the control element 23 is on is supplied to the negative

side terminal of the comparator 25 through a diode 23 for prevention of backward flow, as an element to correct the reference voltage.

Supplied to the positive side terminal of the comparator 25 is a terminal voltage at a point B of a temperature detection element 29 which comprises a plurality of diodes connected in series. The point B is connected to a power line through a resistor R4. Here, the diodes constituting the temperature detection element 29 are formed to be contained in the semiconductor chip which contains the power element 21, so that when the power element 21 is heated by flow of a large current and the semiconductor chip temperature is increased by this heat, the temperature increase of the semiconductor chip can be detected. Further, since the diodes constituting the temperature element 29 have the negative temperature characteristic, and when the semiconductor chip temperature increases, the voltage at the point B decreases according to the temperature increase.

Namely, in the semiconductor device for power comprising as above, the temperature of the semiconductor chip in which the power element 21 is detected by the voltage at the point B of the temperature detection element 29, and the voltage at the point B corresponding to the detected temperature is compared by the comparator 25 with the reference

voltage set by the reference voltage setting unit 27.

The potential at the point B is set higher than the voltage at the point A, when the semiconductor chip temperature is normal. When the semiconductor chip temperature is normal, a high level signal is outputted from the comparator 25 and supplied to the NAND circuit 24 as a gate signal. Therefore, the pulse-like drive signal from the gate drive circuit 26 is polarity inverted and supplied to the power element 21, and the load 22 can be controlled.

When the semiconductor chip temperature increases, the voltage at the point B decreases corresponding to the temperature increase, and when the voltage at the point B decreases to lower than the voltage at the point A, the reference voltage, the output from the comparator 25 changes from high to low level. Namely, the gate signal of the NAND circuit 24 is fixed to a low level and the output signal from the NAND circuit 24 is fixed to a high level, and the control element 23 and power element 21 are turned off, the load current to the load 22 is shut off, and abnormal increase of the semiconductor chip temperature due to an overcurrent can be prevented.

Basically, the above-mentioned protective operation is executed. However, in the semiconductor device for power of this embodiment, the control element 23 similar to the power element 21 is used, and

the gate of the control element 23 is connected common to the gate of the power element 21. Therefore, the control element 23 detects the current flowing in the power element 21. The current proportional to the current flowing the power element 21 flows in the control element 23, and this current flows into the potential part at the point A through a diode 28.

Therefore, the voltage level at the point A or the potential of the negative input side of the comparator 25 is increased by the current flowing through the control element 23, and the temperature difference between the power element 21 of the semiconductor chip and the temperature detection element 29 is corrected.

That is, in the semiconductor device for power of this embodiment, the reference voltage is supplied to the comparator 25 which executes the protective operation against overheating varies corresponding to the load current quantity, in the state where the load current flows in the power element 21, and cancels on the circuit the temperature difference between the power element 21 and temperature detection element 29.

Therefore, when a fault such as a short-circuit occurs in the load 22 during operation of the load 22, the load current flowing in the power element 21 rapidly increases, and the semiconductor chip temperature rapidly rises, the current volume flowing in the control element 23 also rapidly increases, and

the reference voltage supplied to the comparator 25 also increases. Thus, even if the temperature of the preset part of the temperature detection element 29 in the semiconductor chip rises only to 100℃, for example, when the above-mentioned load current increases and the semiconductor chip temperature of the power element 21 rises to 150℃, the reference voltage supplied to the comparator 25 is increased by the current from the control element 23, and the output from the comparator 25 is inverted to a low level even if the temperature detection element 29 detects the chip temperature 100℃. Therefore, when the temperature of the power element 21 in the semiconductor chip rises essentially to 150℃, the current supplied to the load 22 is shut off, and the protective operation is promptly executed.

It is noted that no current flows in the control element when the load is stopped, and the reference voltage is not corrected. In the normal operation state, the quantity of current flowing in the control element 23 is limited, and the correction amount of the reference voltage supplied to the comparator 25 is small. Thus, normal protective operation is executed at a temperature close to the temperature of the preset part of the temperature detection element 29 in the semiconductor chip.

FIG. 2 shows another embodiment of the invention. In this embodiment, resistors R5 and R6 are connected

in series to the control element 23, so that the voltage corresponding to the current volume flowing in the control element 23 can be taken out from a point C. A voltage signal at the point C is supplied to a comparator 30 to be compared with a preset comparing voltage Ref, and when the current flowing in the control element 23 increases and the potential at the point C decreases to lower than the comparing voltage Ref, the voltage for correcting the reference voltage is supplied to the negative side terminal of the comparator 25 through the diode 28 for prevention of backward flow. The other parts are the same as those of the embodiment shown in FIG. 1, and the same reference numerals are given to the same parts, and detailed explanation will be omitted.

In this embodiment, when the load current supplied to the load 23 is relatively small, the reference voltage of the comparator 25 for the protective operation is not corrected, and only when the load current flowing in the power element 21 is extremely increased, the reference voltage of the comparator 25 is corrected.

Further, the p-channel MOS is used as the power element 21 in the above embodiment, but it can be replaced by an n-channel MOS. A bipolar transistor can also substitute for MOS, not limited to a power MOS. Likewise, the temperature detection element 29

comprises a plurality of diodes with different temperature characteristics connected in series in the embodiment, but the diodes can be replaced by other elements with temperature characteristics, such as the ratio of resistors with different temperature characteristics, the potential in a band cap circuit, a Zener diode, or the like. When a power element controlled by a DC drive current is used, the temperature difference is considerably reduced. But in this case, detect only an overcurrent, as shown in the embodiment of FIG. 2, and correct the reference voltage of the comparator 25 only when an overcurrent is actually detected.

In the above-mentioned embodiment, the signal corresponding to the current flowing in the control element 24 is supplied to the reference voltage setting unit 27 of the comparator 25, to correct the reference voltage. However, the same effect can be obtained by using a temperature detection signal as an object of correction.

FIG. 3 shows another embodiment to achieve the above effect. The circuit is basically the same as that shown in FIG. 1. The temperature detection element 29 is connected to the power supply, so that the element 29 is grounded through a resistor R7. The contact point B between the temperature detection element 29 and resistor R7 is connected to the negative

side input of the comparator 25 through a resistor R8. The current from the control element 23 is supplied to the negative side input of the comparator 25 through the diode 28, to correct the temperature detection signal.

Namely, in this semiconductor device, the potential at the point B varies corresponding to the semiconductor chip temperature; as the semiconductor chip temperature rises, the potential at the point B increases. When the semiconductor chip temperature is normal, the reference potential at the point A set by the resistors R1 and R2 becomes lower than the potential at the point B. Therefore, in this state, the output level from the comparator 25 is raised and on-off controlled, supplying the power to the load 22. In this case, a current corresponding to the current flowing in the power element 23 flows in the control element 23, correcting the temperature detection signal.

When a large current flows in the load 22, a large current flows also in the control element 23, giving the comparator 25 a temperature detection signal higher than that actually detected by the temperature detection element 29, so that the operation to protect the semiconductor chip against over-heating is certainly executed.

[Effects of the Invention]

As described hereinbefore, in the semiconductor device for power according to the present invention, when an overcurrent temporarily flows especially in the power element, or when a temperature difference occurs between the power element and temperature detection element in the semiconductor chip, the reference voltage of the protection function unit, which executes temperature detection corresponding to the current quantity flowing in the power element, is corrected. Particularly, when the power element temperature is increased by a temporary current increase, the semiconductor chip temperature is suitably detected. Therefore, the semiconductor device is effectively protected against destruction by heat.

BRIEF EXPLANATION OF THE DRAWINGS

FIG. 1 shows a circuit configuration of a semiconductor device for power according to an embodiment of the present invention. FIG. 2 and FIG. 3 show circuit configurations of another embodiments of the invention. FIG. 4 shows a circuit configuration of a conventional semiconductor device for power.

21…Power element, 22…Load, 23…Control element, 24…NAND circuit, 25…Reference voltage setting unit, 29…Temperature detection element

FIG. 1

a Command signal

22 Load

26 Gate drive circuit

FIG. 2

a Command signal

22 Load

26 Gate drive circuit

FIG. 3

a Command signal

22 Load

26 Gate drive circuit

FIG. 4

a Command signal

13 Load

15 Gate drive circuit